

## Superconducting Spoke Cavities Demonstrate Excellent Performance

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Superconducting radio-frequency (SCRF) cavities have been successfully used in electron accelerators and for high-velocity ( $\beta = v/c = 1$ ) particles and low-velocity heavy ions. However, a recent trend is to apply SCRF technology to intermediate velocity particles by shortening the accelerating gap (which is proportional to  $\beta$ ) in successful  $\beta = 1$  elliptical cavities. However, shortening the gap does not work well for  $\beta < 0.4$  because of mechanical weakness and multipacting within the cavity. A more promising approach is to use a structure called a spoke cavity (also known as a spoke resonator). In tests on a spoke cavity from Argonne National Laboratory, where this technology was originally developed,<sup>1,2</sup> we confirmed that it exhibits good performance. In addition, we designed, procured from industry, and tested two other  $\beta = 0.175$  two-gap spoke cavities in 2002 in support of the Advanced Accelerator Applications (AAA) program at the Los Alamos National Laboratory (LANL).<sup>3-5</sup> These cavities have also shown excellent results.

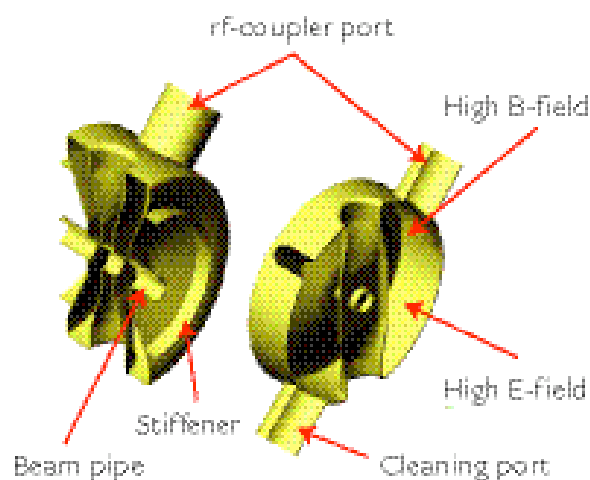
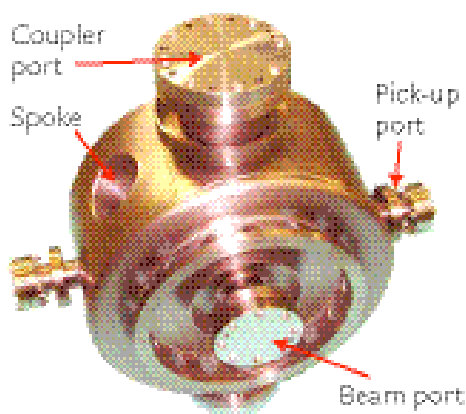


Fig. 1. Cut-away views of the inside of the spoke cavity.

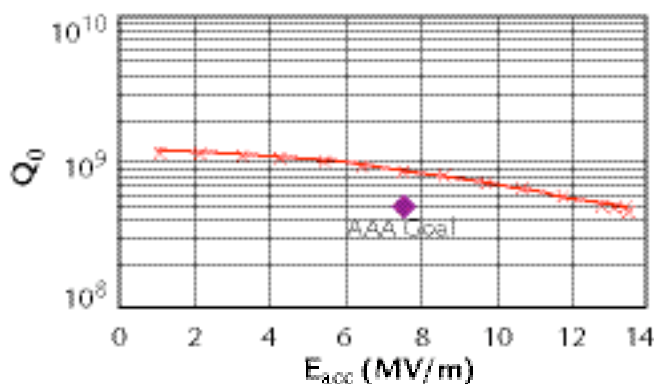
### Testing Spoke Cavities for Advanced Accelerator Applications

Figs. 1 and 2 show cut-away views of the inside of the cavity and a photograph of the cavity. It consists of a spoke in a 40-cm-diam barrel. The particle acceleration occurs in the two gaps between the spoke and the end walls. The 5-cm beam aperture is large enough for the cavity not to be activated by the proton beam.

The major radio-frequency (rf) design parameters are shown in Table 1. The ratios of peak-surface-electric and -magnetic fields to accelerating gradient were well optimized. This has helped our cavities achieve the highest accelerating gradient among other existing cavities in the world.



**Fig. 2.** A photograph of the spoke cavity, which is made of 3.5-mm-thick niobium sheets. Two cavities were fabricated on schedule by E. Zanon, an Italian manufacturer of pressure vessels.



**Fig. 3.** The cavity quality factor  $Q_0$  as a function of accelerating gradient  $E_{acc}$ . These data are of the first cavity (EZ01). The second cavity (EZ02) exhibited a similar curve and reached an  $E_{acc}$  of 12.9 MV/m.

Table 1. rf design parameters. <sup>3</sup>	
$Q_0$ (4 K)	$1.05 \times 10^9$ (for 61 n $\Omega$ )
$T$ ( $\Omega$ g)	0.7765 ( $\Omega$ g = 0.175)
$T_{max}(\Omega)$	0.8063 (at $\Omega = 0.21$ )
$G$	64.1 $\Omega$
$E_{pk}/E_{acc}$	2.82
$B_{pk}/E_{acc}$	73.8 G/MV/m
$P_{cav}$ (4 K)	4.63 W at 7.5 MV/m
$R/Q$	124 $\Omega$

## Test Results

We tested the mechanical properties at room temperature and measured the cavity quality factor ( $Q_0$ ) as a function of accelerating gradient ( $E_{acc}$ ).<sup>4</sup> Fig. 3 shows the  $Q$ - $E$  curve of one of the cavities. This cavity (EZ01) reached an  $E_{acc}$  of 13.5 MV/m, and the second cavity (EZ02) reached an  $E_{acc}$  of 12.9 MV/m. The design goal of the AAA project is 7.5 MV/m with a  $Q_0$  of  $5 \times 10^8$  (i.e., a loss of  $\sim 10$  W). Our excellent results ensure the highly reliable operation required for transmutation of waste projects.

## Future Prospects

Because of increased interest in spoke cavities, we held an international workshop on this subject at LANL in October 2002.<sup>6</sup> It is likely that spoke cavities will be developed and used for future proton and heavy-ion accelerators designed for studies in neutron science, nuclear waste transmutation, rare-isotope physics, and other related areas.

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## References

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3. F.L. Krawczyk et al., in *Proceedings of the European Particle Accelerator Conference* (2002).
4. T. Tajima et al., in *Proceedings of the International Linear Accelerator Conference* (2002).
5. See <http://laacg1.lanl.gov/scrflab/spoke.html>.
6. See <http://laacg1.lanl.gov/spokewk/>.

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